PHOTO: AXEL GRIESCH

Deceptive silence: Holger Goerlitz needs a large amount of technical equipment to be able to hear the ultrasonic calls emitted by the bats.

GETTING THEIR BEARINGS

TEXT: UTA DEFFKE

Two shadows flit around in the evening light. A bat is chasing after a moth in a wild dance between hunter and prey. For Holger Goerlitz, pursuits like this one are a real thrill. The leader of an Emmy Noether Research Group at the Max Planck Institute for Ornithology in Seewiesen is researching how bats and insects use sound to detect each other.

SUMMARY

Bats are able to orient themselves by emitting calls in the ultrasonic frequency range. They calculate the distance of an object from the time elapsed between their call and its echo. The size, surface structure and position of the object are indicated, among other things, by changes in the frequency, duration and volume of the echo.

Many prey species have adapted to the echolocation strategies of bats. Moths have developed particularly good hearing in the frequency ranges used by their predators, and use evasive maneuvers in flight. Bushcrickets also adapt their chirping to protect themselves against attacks by bats.

The sense of hearing evolved in moths and bushcrickets to communicate and to perceive the surrounding, and not as a reaction to echolocation.

Many animals have the ability to hear. Sound can carry over very long distances, and obstacles hardly muffle it at all. Nocturnal animals in particular rely on their sense of hearing because, unlike their eyes, their ears are also effective in darkness.

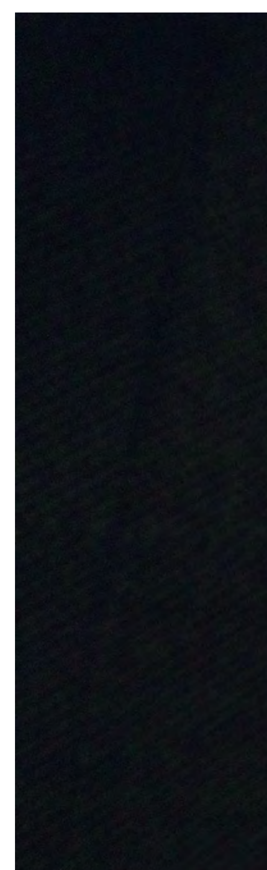
Bats are perfect examples of what extraordinary feats the sense of hearing can accomplish. The animals emit sounds and analyze the echoes that are reflected back by their surroundings. To do this, they usually use ultrasound, in other words, frequencies that lie above the audible range of the human ear. "So for us, the sounds bats make are usually inaudible. And we should be glad about this, because the volume of bat calls reaches the level of a jackhammer or even a jet plane," Holger Goerlitz explains. The bats calculate their distance from an object according to the time that elapses between the moment they emit their call and the moment they hear the echo back. Fluctuations in the frequency – the pitch of the sound – as well as the duration and volume of the echo also inform the animals as to whether the object is large or small, smooth or rough, stationary or flapping its wings. This is how they can identify obstacles, find potential prey and even communicate with other members of their own species. This is not so easy in the natural world, because bats are moving within complex sound environments during their nightly hunting excursions. Other bats of the same or different species are calling, moths are flying about, bushcrickets are singing, beetles rustle on the ground, and leaves shake in the wind.

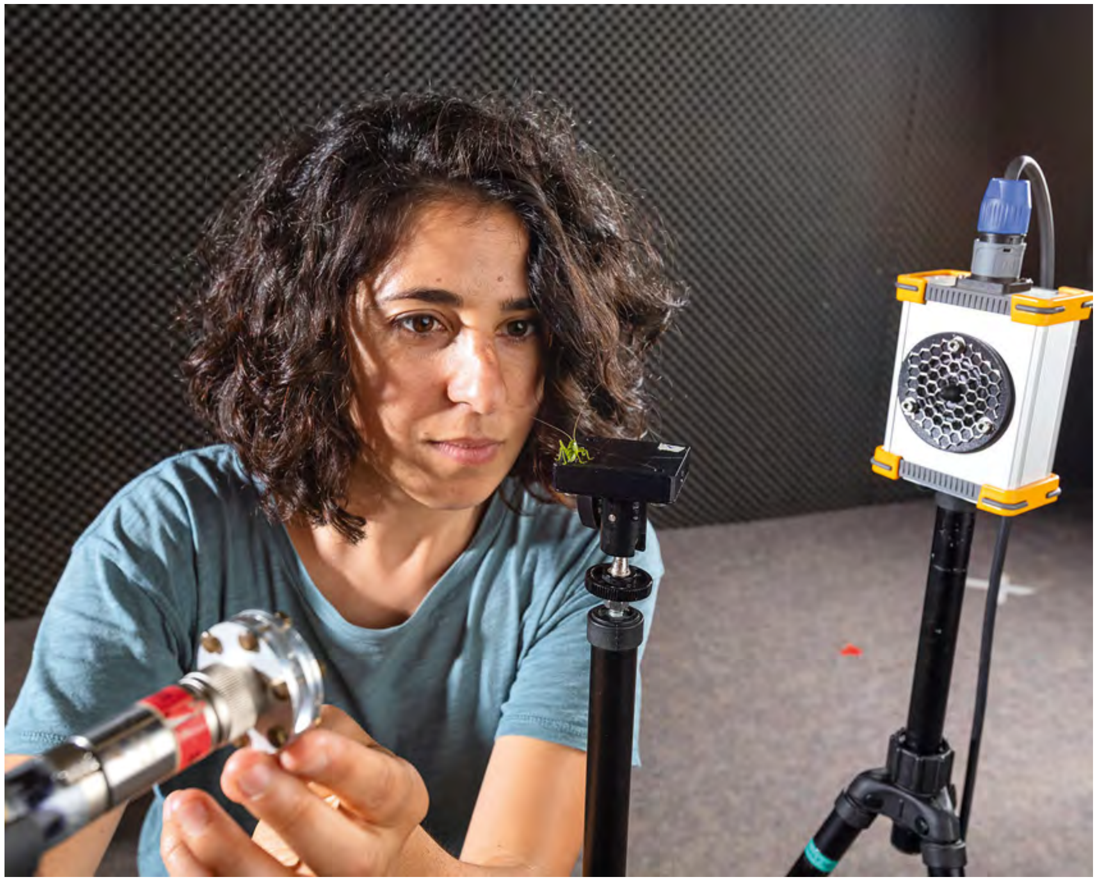
Goerlitz and his team are observing the animals in their natural environment and in laboratory experiments to study the sensing and orientation strategies used by bats and their prey. The group is operating a small research station in a village in northeastern Bulgaria. Rivers have carved themselves deep into the rocks of the region's karst landscape and a large number of caves have been created at their edges. This environment provides roosting sites and food for many different bat species. "This is ideal territory for field research and laboratory experiments," Holger Goerlitz enthusiastically explains.

The researchers capture the winged hunters at night as they fly in and out of the caves, and then fit them with sensors. Since bats are nocturnal, the experiments are usually conducted in the first few hours after sunset. By setting up arrays with four to 22 microphones, the researchers record the calls of passing bats and analyze their flight paths and the direction of their calls. Using the tiny differences in the time that it takes each call to reach all of the microphones, the researchers calculate the three-dimensional location of the animals. On the other hand, microphones placed just next to the prey species measure what they hear from the approaching predators. Then, the researchers have to sit and wait. They're wrapped up in several layers of clothing, since it can get pretty cold in northern Bulgaria, even in the spring and fall months. "The most spectacular time is just before it gets completely dark, when we are still able to observe the bats and their behavior ourselves," Goerlitz says.

But some experiments can only be conducted in the laboratory. Both at the station in Bulgaria and at the Max Planck Institute in Seewiesen, the researchers use soundproofed flight rooms equipped with loudspeakers and microphones. These rooms are of course kept completely dark, in keeping with the animals' nocturnal rhythm. The laboratory experiments have shown the researchers that the bats constantly adapt their echolocation to the specific environment and task. In the open air they emit regular calls at low frequencies, since these travel particularly far. As a result, they can detect obstacles and prey over longer distances. In contrast, when flying in more confined spaces, when landing or when approaching prey, the bats' calls get shorter, contain more frequencies and are repeated more often. In this way, the animals optimize different aspects of the echoes to obtain more and more precise information about their environment from the returning echoes. "Thus, with their calls, bats let us know what they are currently interested in," says Goerlitz.

Recently, the researchers have begun utilizing portable mini-measuring stations to study the strategies that bats use when approaching prey. Fitted with sensors, these devices are attached to the backs of the bats, and throughout the night, they collect data about the natural behavior of the animals in the wild. In this way, Goerlitz and an international team of colleagues have discovered how the bats can differentiate between their prey and other objects in the background. "Just before they attack, the background echoes disappear and the acceleration sensors kick in. In other words, shortly before they attack, the bats turn away from the background and towards their prey. In this way, they fade out the background and focus on the prey," Goerlitz explains. But the prey insects have their own defense mechanisms against attacking bats. Moths, for example, can hear the echolocation calls made by the bats and react to the predators with sophisticated





Right:
In the laboratory, Antoniya Hubancheva replays the hunting calls of a bat to a bushcricket and measures the insect's reaction.

Below:
Most bats are very delicate creatures. A young pale spear-nosed bat like this one held by Holger Goerlitz weighs just around 15 grams.

PHOTOS: AXEL GRIESCH

The greater mouse-eared bat can localize its prey even in absolute darkness. To do so, it uses echolocation and its finely tuned sense of hearing.

PHOTO: CARSTEN BRAUN / FOTOFINDER

PHOTO: STEFAN GREIF

Lesser and greater mouse-eared bats, common bent-wing bats and long-fingered bats in the Gabarnika Cave. The animals form huge colonies of tens of thousands of bats. They rear their young in the karst caves in northeastern Bulgaria, where they also roost during the winter months.

evasive maneuvers. This is surprising, since the insects have only a very simple ear. It consists of just one eardrum and two nerve cells with different levels of sensitivity. As a result, the moths can perceive a broad frequency range and hear a bat as it attacks, but they are unable to differentiate between individual frequencies.

Jointly with a colleague from the U.S., Goerlitz has discovered that the moths' sense of hearing is adapted to the local bat population. For example, if bat species that call at a higher frequency are living in a region, the ears of the local moths are more sensitive within this frequency range as well. The moths respond to a bat attack with a two-stage evasive maneuver. If the bat is still far away, and its call is relatively faint, they try to escape via the direct route. However, if the predator comes closer and its calls become louder, the insects fly in a zig-zag pattern or in spirals, or they drop to the ground. This variation in evasive maneuvers makes it difficult for the hunters to catch their prey. The researchers want to find out whether moths use different evasive maneuvers and which of these are the most successful. For example, it might be the case that every moth utilizes all available flight strategies. However, it may also be possible that moths only have one of these strategies available, in which case the variety of evasive maneuvers would be a group phenomenon. The researchers have been studying this hypothesis in the laboratory, using highly sensitive technology to measure the reaction of seven species of moths when they hear recordings of bat echolocation calls. The experiments have shown that each species of moth uses different maneuvers. Among some species, there are even differences between individual moths. "Since several species of moth live in one habitat, this diversity provides additional protection against the predators, since a bat is unlikely to differentiate between the various species of moth. As a result, it cannot know how the prey will react," says Goerlitz.

To date, the researchers only understand the features of the two nerve cells that are activated immediately by the vibrating eardrum. However, they know almost nothing about what happens to this information in the moth's brain. Therefore, Goerlitz and his team also want to find out more about the neuronal basis for these types of behavior. "For example, how are the sensory inputs to the left and right ear combined? Or how long does it take for a reaction to occur after the sound has entered the ear, and how is hearing influenced by other stimuli, such as light or the pheromones of female moths?" To learn even more about

For their studies, the researchers also investigate bats in the laboratory.
The bats are captured in fine-mesh nets, from which they are carefully extricated.

PHOTO: STEFAN GREIF

the strategies that evolved in prey species to outsmart their attackers, Holger Goerlitz and his team are also studying bushcrickets. Bushcrickets primarily use sounds to communicate with each other. But this could reveal their location to bats, which not only actively emit echolocation calls, but also passively listen for sounds generated by their prey; so the bushcrickets have to adapt their communication to their nocturnal predators. For this reason, some bushcrickets stop chirping when bats are close by. However, some species don't let themselves get distracted by the hunters flitting around them and continue to sing as before. "Interestingly, these are species that chirp with a fast rhythm and at high frequencies. It is possible that their chirps superimpose the echoes from the surrounding in such a way, that the bats are no longer able to orient properly in their habitat," Holger Goerlitz explains.

The first laboratory data appears to confirm this idea. When bats hear the songs of bushcrickets via loudspeakers, they are less successful in catching their prey. When several bushcrickets sing simultaneously, it could also create a similar stereo effect to the one we hear from our stereo systems. Although the same sound is coming from two sources (the speakers), we do not perceive them as being separate.

Instead, we localize the sound within the center between them. The bats might experience a similar phenomenon, making it difficult for them to perceive and locate their prey as individual targets.

In summary, the researchers have observed various adaptations of the prey species in response to the hunting strategies used by the bats. Have the bats responded in turn, meaning that a kind of "arms race" is taking place between the hunters and their prey? "For many years, it was thought that this was the case. Bats and moths were considered a textbook example of coevolution between predators and prey," Goerlitz says. One of his discoveries initially appeared to confirm this view. Barbastelle bats mostly hunt moths that have a sense of hearing. Their calls are ten times quieter than those of other bat species. And the closer they come to the moth, the quieter they become. This enables the animals to outwit their prey's auditory senses and catch the moth. However, the disadvantage of this hunting strategy is that the barbastelle bat only receives faint echoes from its environment, and therefore is almost flying blind. The fact that it is willing to accept this handicap suggests that the advantages of its quiet echolocation for hunting compensate for its disadvantages during orientation.

However, Goerlitz no longer agrees with this idea, and is investigating an alternative explanation. Many close relatives of the barbastelle bat hunt along the edges of forests and bushes and above meadows by listening for the rustling sounds made by insects. At such proximity to the vegetation, loud orientation calls also generate loud echoes from the vegetation. In addition, they mask the quiet rustling sounds of the insects. Possibly the ancestors of the barbastelle bats began to call more quietly to prevent this masking. The advantages of quiet echolocation for hunting prey with ears in open spaces would have been a secondary effect that the barbastelle bats only began to exploit later on. It was also assumed for a long time that the sense of hearing in moths had evolved in response to predation by bats. However, there are now indications that the moths were already able to hear millions of years before bats came on the scene. If that is true, then their sense of hearing evolved to communicate and as a general sense of their environment, and not as a specific reaction to nocturnal predators. "As you can see from this example, it is often difficult to determine the cause of an evolutionary development with any certainty," Goerlitz explains.

"However, there is a simple reason why moths have adapted in more ways to bats than the other way around," says Goerlitz. "For the prey, the pressure to succeed is far higher, since for them, it is nothing less than a matter of life and death. For the predator, however, all that is at stake is another meal."

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